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ABSTRACT

The ability to use sequential constraints in recognizing letters in three-letter words flashed on a screen at low contrast thresholds and the relationship of this ability to grade level and reading achievement were investigated. Eighty subjects were randomly selected, 20 each from grades 1 through 4. Ten adults were also tested for comparison with the children. The 28 test stimuli were composed of 12 three-letter words and their component letters. When the letters were presented individually, the other two positions were filled with blanks. Each stimulus was initially projected at below-contrast threshold, and contrast was gradually increased until recognition was possible. There was an increase in mean gain for both words and letters with grade level, with a slight drop for adults, but these differences were not statistically significant. A zero correlation was found between Stanford Achievement Tests reading subscores in grades 2, 3, and 4 and recognition gain. There was a significant relationship between the difficulty in recognizing a particular letter within a word and the difficulty in recognizing the other letters in the word. A higher proportion of like-class confusions (vowels confused with other vowels) were made in the word condition than in the letter condition. References are included. (CM)

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# The Use of Redundancy By Beginning Readers

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# THE USE OF REDUNDANCY BY BEGINNING READERS*

Deborah Lott and Bruce Cronnell

Printed English is not composed of random sequences of letters. Some letters occur more often than others; some letters occur more often within the context of certain other letters. If a skilled reader is shown a sequence of letters from actual text, he can predict the next letter with far better than chance accuracy (Carson, 1961). The skilled reader's ability to make such predictions indicates that he uses the redundancy present in printed English.

Redundancy describes the extent to which a sequence of letters is non-random or predictable. The major sources of language redundancy are: (1) distributional constraints or the redundancy due to unequal usage of letters in the language, and (2) sequential constraints or the redundancy due to the probabilities that certain letters will be preceded or followed by certain other letters. The amount of redundancy due to distributional constraints is small relative to that due to sequential constraints (Garner, 1962, p. 252).

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The extent to which redundancy is used in word recognition depends largely on the language skills of the reader (Garner, 1962). Chapanis (1954) found that adult ability to use redundancy in reconstructing abbreviated text correlates highly (r's range from 63 to .68) with scores on the Wonderlic Personnel Test and on the Cooperative English Test.

If the skilled reader makes efficient use of sequential constraints as a result of his knowledge of printed English, when does the beginning reader develop this skill? An exploratory study on the use of redundancy by beginning readers found that kindergarten children who had completed a beginning reading program (SWRL First-Year Communication Skills Program) showed no tendency to use sequential constraints in the recognition of familiar three-letter words, whereas the third and fifth graders did use sequential constraints. The change in performance between kindergarten and third grade raised the question of when this skill develops during the intervening years.

The extent to which a subject uses sequential constraints is measured here by the difference between the amount of information he requires to recognize letters presented individually with position indicated and the amount of information he requires to recognize the same letters, in the same positions, in a three-letter word. This difference is called a mean gain.

Based on the exploratory work by the authors and by others (Smith, 1968; Garner, 1962; Chapanis, 1954; Carson, 1961), the following predictions concerning the use of redundancy by beginning readers will be examined here:

(1) Mean gain will increase with grade level, indicating an increasing ability to make use of sequential constraints in word recognition.

(2) Recognition threshold of letters presented individually will decrease as grade level increases, thus indicating that the younger children need more information to recognize letters presented individually.

(3) There will be a positive correlation between the amount of mean gain exhibited by the children and their scores on the reading sections of the Stanford Achievement Test. The existence of such a correlation implies that knowledge of sequential constraints is related to reading ability for children as well as adults (Chapanis, 1954).

There will be a negative correlation between the contrast threshold at which letters are recognized when they are presented individually and scores on the reading sections of the Stanford Achievement Test. The existence of such a correlation implies that there is a negative

relationship between the amount of information required to recognize letters presented individually and reading ability.

(4) The difficulty in recognizing a particular letter in a word is related to the difficulty in recognizing the other letters in the word (e.g., the difficulty with t in but, hat, let, and wet will be related to the difficulty of bu, ha, le, and we). The presence of this relationship will further demonstrate the influence of sequential constraints on letter recognition. This prediction was supported in an earlier study with adult subjects (Smith, 1967).

(5) When a subject is presented with a word he will have more information concerning the class (vowel or consonant) of each letter of the word than he would if presented with the letter in isolation. Therefore, he will make a higher proportion of like class letter confusions (vowels confused with other vowels; consonants with other consonants) in the word condition than in the letter condition. Furthermore, the proportion of like class confusions will increase with grade level.

## METHOD

### SUBJECTS

Eighty subjects were randomly selected, 20 each from grades 1 through 4. All first graders had successfully completed the SWRL First-Year Communication Skills Program. All subjects were from the same school, except 10 first graders.[1]

Children entering grade 1 and children entering grade 4 provided the lower and upper age limits for the study. These age limits were selected on the basis of the preliminary finding that at the completion of kindergarten children do not use redundancy and at the completion of grade 3 they do.

Ten adults (SWRL staff members) also were tested to provide a comparison with the children's performance.

### TEST ENVIRONMENT

All testing was conducted in a mobile laboratory at the children's school. The children were released from their classes one at a time

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[1] There was not a significant difference in the performance of the first grade children from the two schools.

and taken by the experimenter to the mobile laboratory. Adults also were tested individually in the mobile laboratory.

## MATERIALS

Twenty-eight test stimuli were used. The stimuli consisted of 12 three-letter words from the SWRL First-Year Communication Skills Program (but, did, fun, hat, let, man, men, ran, sad, sun, wet, win) and their component letters. When the letters were presented individually the other two positions were filled with "boxes" (#) -- for example, when the component letters of fun were presented individually, they occurred as follows: f##, #u#, ##n.

Stimuli were typed in lower case IBM Delegate type, photographed and rephotographed on orthochromatic film to provide positive transparencies with maximum contrast between opaque areas (the letters) and the transparent ground, and mounted for presentation by a Kodak Carousel projector.

## PROCEDURE

Each stimulus was initially projected at below contrast threshold. Contrast was gradually increased until recognition was possible. The stimulus--approximately 1½ by 3 inches--was projected onto a 5 by 7 inch white card, five feet from the subject, in a lighted room. Lighting consisted of four 40-watt lights, two on each side of the subject, approximately 2 feet away; one of each pair was 1 foot in front of the subject, the other 4 feet in front of the subject. In addition, 2 feet behind the subject there was a 60-watt light filtered through 70% transmission Opalglass. The light intensity of the projector was controlled by a variable transformer which varied the contrast level in approximately 0.6 volt steps.

The experimenter (the same for all subjects) asked the subject to report verbally the letter or letters which he was able to recognize and the positions in which the letters occurred.[2]

Eight trial stimuli were used to familiarize each subject with the technique. For the first four trials, the subject was told whether to expect a word or a letter; for the remaining four trials, and all the

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[2] Because of the irregular and sometimes lengthy exchanges which occurred between the subject and the experimenter, stimuli were projected for unequal time intervals at the different contrast levels. However, preliminary research with with technique revealed that time interval length has no appreciable effect.

actual testing, he was not told what to expect. The subject was not told of the trial-test distinction. Data were obtained on all 28 test stimuli for all subjects. Four randomly ordered presentation lists were compiled and each subject was randomly assigned to one of these four lists.

During the first four trials, each subject was asked, at each contrast level, to report what letters he saw, always noting the position (beginning, middle, end) of each letter reported. As the subject became familiar with the technique, the prompting was reduced. Projection of a stimulus ceased when recognition occurred.

## RESULTS

Mean gain values for each grade level and the adult group are shown in Figure 1. As predicted, there was an increase in mean gain with grade level, with an unpredicted, slight drop for the adults. However, a Kruskal-Wallis one-way analysis of variance by ranks (Siegel, 1956, pp. 185-194) failed to show these differences to be statistically significant, both when the children's scores were examined alone ($H = 7.30$; $p > .05$) and when the adults' scores were included ($H = 6.63$; $p > .05$).

The prediction that letters presented individually would be identified at a higher contrast level by the younger subjects was supported ($H = 10.43$; $p < .05$). As Figure 2 shows, the adult subjects had markedly lower thresholds than the children, whereas older children had only slightly lower thresholds than younger ones.

There was zero correlation of performance on the reading sections of the Stanford Achievement Test with the amount of mean gain or with the contrast level at which letters presented individual were recognized. Spearman-rho coefficients of correlation for rank ordered data ranged from -0.23 to 0.15 when the grades[3] were examined individually, all of which were insignificant ($p > .05$).

As predicted, there was a significant relationship between the difficulty in recognizing a particular letter within a word and the difficulty in recognizing the other two letters in the word. A Median Test (Siegel, 1956, pp. 111-115) was used to examine the relationship between the threshold at which a single letter in a word was recognized[4] and the threshold at which the other letters in the word were recognized. This

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[3] Only grades 2, 3, and 4 were examined, as Stanford Achievement Test scores for grade 1 and for adults were not available.

[4] Analysis was performed only on those letters which occurred in three or more words.

relationship was found to be significant ($X^2 = 88.92$; $p < .001$)[5] was maintained across grades 1 to 4 and adults.

The prediction that a subject would make a higher proportion of like class confusions (vowels confused with other vowels; consonants with other consonants) in the word condition than in the letter condition was supported. This prediction was tested by finding the size of the difference when the number of unlike class confusions (vowels confused with consonants; consonants with vowels) was subtracted from the number of like class confusions. Since there was wide variability in the number of total confusions made across individual subjects, weighted scores for the size of these differences were calculated. Weighting was accomplished by recording the number of the two confusion types in the two presentation conditions for each subject, subtracting the number of unlike class responses from the number of like class responses, and dividing the result by the subject's total number of errors in that condition. A two-way analysis of variance for repeated measures and with unequal cell size (Winer, 1962, pp. 96-104, 298-318) was used to examine condition effects (words versus individual letters) and grade effects. When the data for the children were examined alone, the results revealed no significant grade effect ($F = 1.69$; $p < .05$) and no interaction effect ($F = 0.47$; $p > .05$) but a highly significant condition effect ($F = 23.55$; $p < .001$). When adult subjects were included in the analysis, the grade and interaction effects remained insignificant ($F = 2.07$; $p > .05$ and $F = 0.99$; $p > .05$ respectively) and the condition effect significant ($F = 32.55$; $p < .001$). Figure 3 demonstrates the mean values of the weighted scores obtained for the different grades in the two conditions.

## DISCUSSION

It was predicted that use of sequential constraint, as revealed by mean gain, would increase with grade level. The results demonstrated the existence of such a trend although this trend was not statistically reliable. This finding is in apparent opposition to that of the exploratory study, in which a significant difference in mean gain was observed between kindergarten and grade 3. Since this earlier study had revealed a significant difference, a U-test was run between the mean gains obtained in grades 1 and 4. The difference between these two groups was significant at the .01 level ($U = 104.5$), thus replicating the earlier finding.

The prediction that the recognition threshold for individually presented letters would decrease as grade level increased was supported.

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[5] Only those cases in which recognition of the word did not occur at a single contrast level were examined.

However, the trend across grades 1 to 4 was minor; as shown in Figure 2, the adult group contributed most to the obtained effects. The markedly superior performance of the adults was perhaps attributable to their having greater knowledge of distributional constraints, or single letter probabilities, than the younger subjects.

However, differences in letter recognition thresholds could also have arisen from differing ability to use the featural redundancy present in individual letters. Featural redundancy is defined as the probability that certain features will occur with other features. This definition differs little from Garner's definition of sequential constraints (Garner, 1962, 252) except that the language units under consideration are features rather than whole letters. Redundancy on a featural level allows for the possibility of constraints within a single letter due to non-random relationships among its features. Therefore, the older reader, with greater knowledge of the featural constraints holding for single letters, would be expected to recognize isolated letters at a lower contrast threshold than the younger reader, simply because he needs less featural information for recognition. However, the effects of featural redundancy and distributional constraints cannot be isolated in this study. Therefore, only tentative conclusions may be drawn.

The lack of correlation of Stanford Achievement Test scores of reading ability with mean gain and with mean contrast level for recognition of letters presented individually was not expected, since Chapanis (1954) found a positive correlation between adults' ability to use redundancy, and their performance on both the Wonderlic Personnel Test and the Cooperative English Test. Differences in construction of the tests may account for the inconsistency of results from the present test with those of tests used by Chapanis. For example, use of sequential constraints may not be considered an important component of reading skill in the Stanford Achievement Test.

The positive relationship between recognition thresholds for single letters and recognition thresholds for the other two letters in a word implies that sequential constraints were used at all grade levels.

Similarly, the presence of a significant condition effect and the absence of a significant effect in the confusion class analysis supports the conclusion that children from all age levels were making use of sequential constraints in recognizing the three-letter words presented to them.

## CONCLUSION

A few conclusions may now be drawn about the use of redundancy by beginning readers. It is clear that knowledge and use of sequential

constraints develop quite early in reading, at least where three-letter, familiar words are concerned. Children of all ages demonstrated a sophisticated knowledge of the structure of simple three-letter words. The results suggest that this knowledge increases with grade level up to about grade 4, when approximately adult sophistication is achieved. Research should now be conducted with longer sequences of letters and less familiar words to determine more precisely how knowledge and use of redundancy develop as children learn to read.

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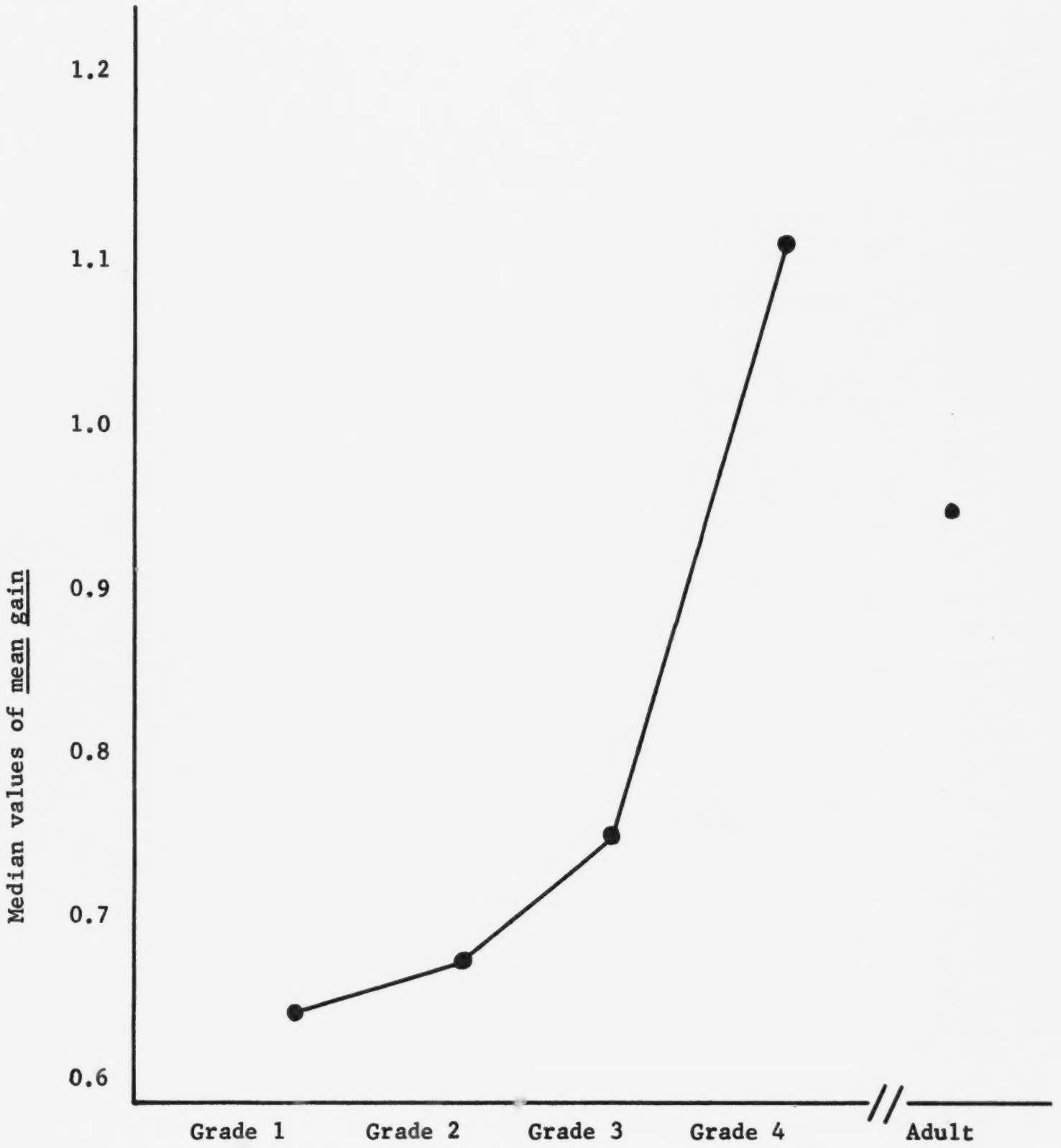


Figure 1: Median values per grade on mean gain.

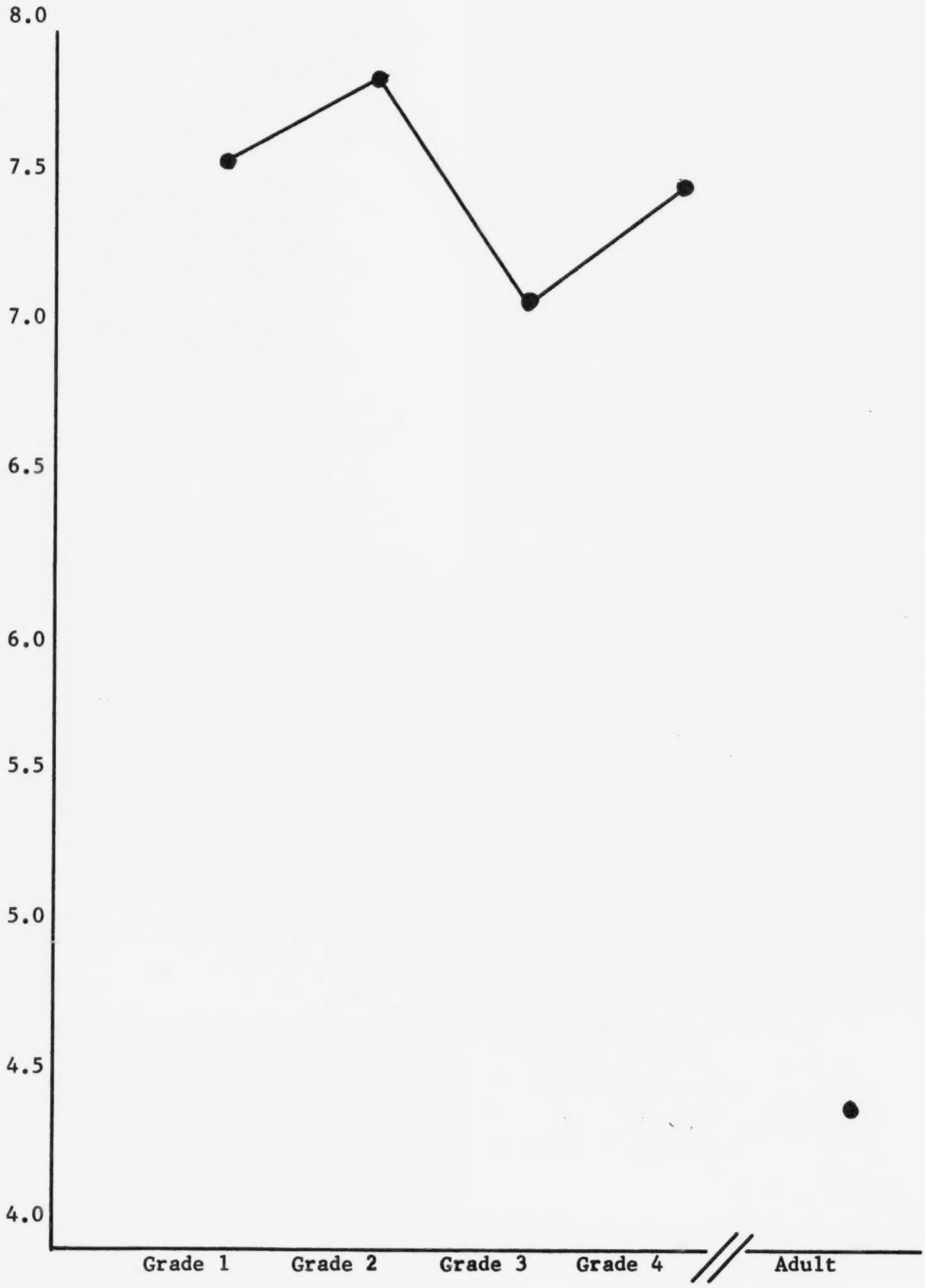


Figure 2: Median values per grade for contrast level at which letters presented individually were recognized (I scores).

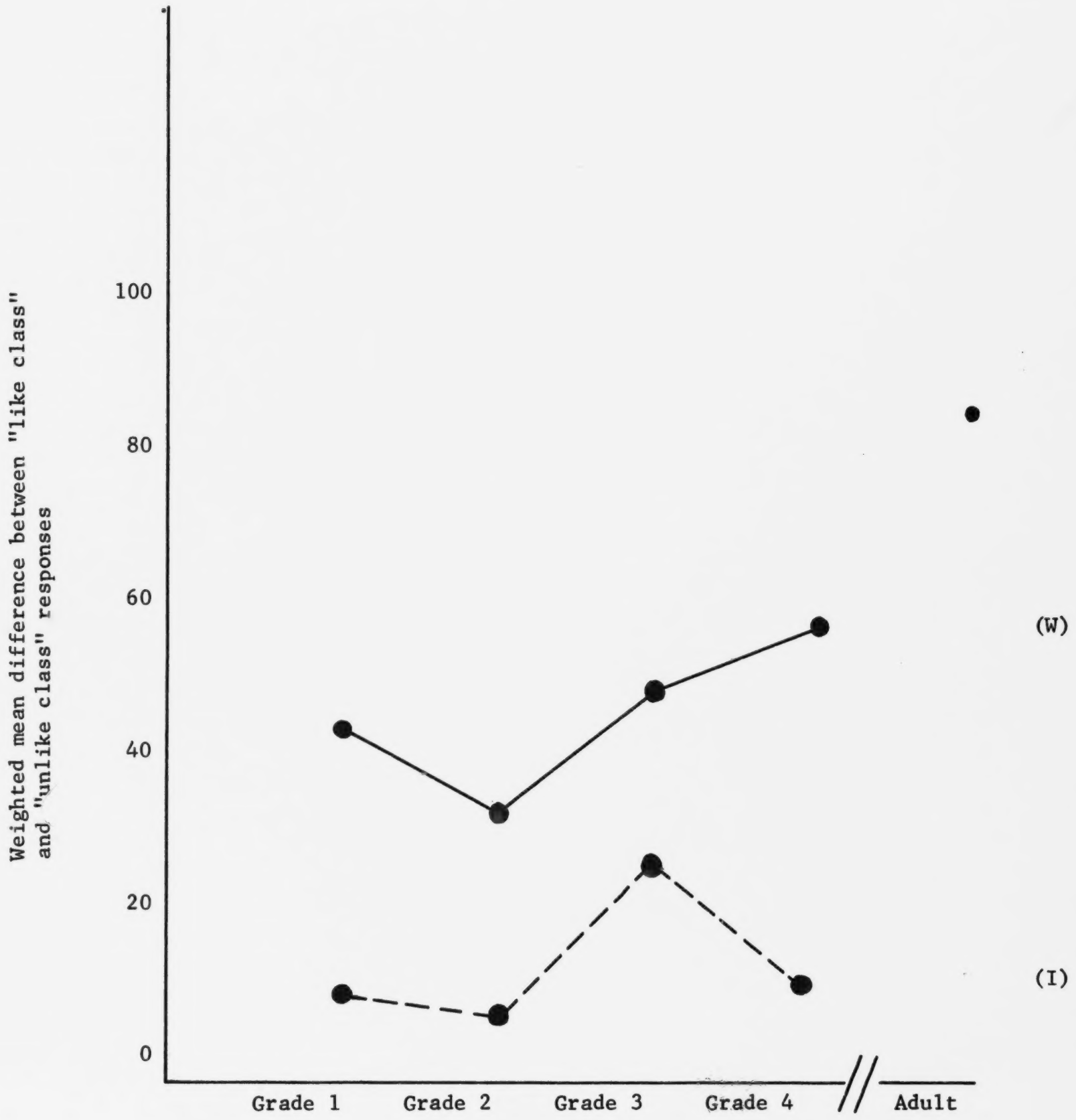


FIGURE 3: Mean weighted score differences between "like class" and "unlike class" responses for letters presented in words (W) and letters presented individually (I) as a function of grade level.